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Quantum Photonic in Hybrid Cavity Systems with Strong Matter-Light Couplings

Hui Deng
UNIVERSITY OF MICHIGAN

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14. ABSTRACT
A novel, designable microcavity structure was developed in the project for exploring new manybody physics and quantum-device applications of property-designed quantum liquids. Specifically the following was achieved:
1. Strong-coupling between quantum-well excitons and cavity photons was demonstrated in the designable microcavity structure for the first time, establishing a robust light-matter hybrid states with designable properties. [Ref 1, 6]
2. Confinement and coupling of microcavity polaritons were readily implemented by design of the photonic crystal in the new cavity structure, allowing flexible device design and integration of the polariton system. Zero-dimensional polariton systems were created by reducing the area of the photonic crystal, coupling between multiple zero-dimensional polariton systems was controlled by design of the boundaries of the photonic crystals, and quasi-1D polariton featuring band-structures was also demonstrated. [Ref. 1-2, 6]
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Quantum Photonic in Hybrid Cavity Systems with Strong Matter-Light Couplings

Report Period: 7/1/2012-6/30/2015

Principal Investigator: Professor Hui Deng

Institution: University of Michigan

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In this project, a novel, designable microcavity structure was developed for exploring new manybody physics and quantum-device applications of property-designed quantum liquids. Specifically the following was achieved:

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3. Spin-selectivity of the polaritons was demonstrated in the new cavity structure, enabling single-mode polariton lasing without ground-state degeneracy. The unique magnetic field response of polariton condensation in single linearly-polarized state was also studied. [Ref 1, 3, 6]
4. Energy-momentum dispersion engineering of high-quality vertical microcavities was demonstrated theoretically and numerically utilizing the unique symmetry properties of the photonic crystal mirror. The curvature of the dispersion, controlling the effective mass, group and phase velocities and the density of states of the modes, can be varied by orders of magnitude. Even flat-bottom or Mexican-hat shaped dispersions could be created. This opens the door to creating photonic and polariton systems where the light propagation and matter-light interactions can be controlled by design without introducing loss or decoherence to embedded active media. [Ref 4]
5. A polariton laser with full intensity stability at the Poisson noise limit, a defining feature of coherent light, was demonstrated with the new cavity. Strong nonlinear interactions within the condensate, critical for polariton-based nonlinear devices, was measured and was shown to be greater than the decay rate of the condensate at high condensate occupancy numbers. [Ref 5]

The project supported three Ph.D. students, including one graduated in 2015 with a dissertation submitted [Ref 6]. Main achievements in the dissertation include items 1-3 above.

Publications:

[1] Zhang, B., Wang, Z., Brodbeck, S., Schneider, C., Kamp, M., Höfling, S. & Deng, H. "Zero-dimensional polariton laser in a subwavelength grating-based vertical microcavity." Light Sci Appl 3, e135 (2014). http://www.nature.com/lsa/journal/v3/n1/full/lsa201416a.html

[2] Fischer, J., Brodbeck, S., Zhang, B., Wang, Z., Worschech, L., Deng, H., Kamp, M., Schneider, C. & Höfling, S. "Magneto-exciton-polariton condensation in a sub-wavelength high contrast grating based vertical microcavity." Applied Physics Letters 104, 091117 (2014). http://scitation.aip.org/content/aip/journal/apl/104/9/10.1063/1.4866776

[3] Zhang, B., Brodbeck, S., Wang, Z., Kamp, M., Schneider, C., Höfling, S. & Deng, H. "Coupling polariton quantum boxes in sub-wavelength grating microcavities." Applied Physics Letters 106, 051104 (2015). http://scitation.aip.org/content/aip/journal/apl/106/5/10.1063/1.4907606

[4] Wang, Z., Zhang, B. & Deng, H. "Dispersion Engineering for Vertical Microcavities Using Subwavelength Gratings." Phys. Rev. Lett. 114, 073601 (2015). http://link.aps.org/doi/10.1103/PhysRevLett.114.073601

[5] Kim, S., Zhang, B., Wang, Z., Schneider, C., Brodbeck, S., Hofling, S., Kamp, M. & Deng, H. "Coherence Properties of a Single-Mode Polariton Laser." Frontiers in Optics 2014 LW2I.2 (2014). http://www.opticsinfobase.org/abstract.cfm?URI=LS-2014-LW2I.2

[6] Zhang, B. "Low Dimensional Polariton Systmes in Subwavelength-Grating Based Microcavities." Doctoral thesis. (2015). http://deepblue.lib.umich.edu/handle/2027.42/111358

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HUI DENG

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Abstract

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1. Zhang, B., Wang, Z., Brodbeck, S., Schneider, C., Kamp, M., Höfling, S. & Deng, H. “Zero-dimensional polariton laser in a subwavelength grating-based vertical microcavity.” Light Sci Appl 3, e135 (2014). http://www.nature.com/lsa/journal/v3/n1/full/lsa201416a.html

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6. Zhang, B. “Low Dimensional Polariton Systmes in Subwavelength-Grating Based Microcavities.” Doctoral thesis. (2015). http://deepblue.lib.umich.edu/handle/2027.42/111358

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Laboratory Task Manager

Program Officer

Research Objectives

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Supplies			
Total			

Report Document

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Appendix Documents

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